Title	A study on search performance and beam-forming method of multi-beam radar(ABSTRACTS (PH D FOR GRADUATE SCHOOL OF INFORMATICS))
Author(s)	Matsuda, Shoji
Citation	Sustainable humanosphere : bulletin of Research Institute for Sustainable Humanosphere Kyoto University (2006), 2: 26-27
Issue Date	2006-08-31
URL	http://hdl.handle.net/2433/51101
Right	
Type	Departmental Bulletin Paper
Textversion	publisher

A study on search performance and beam-forming method of multi-beam radar

Shoji Matsuda
Research Institute for Sustainable Humanoshere (RISH), Kyoto University

Multi-beam search-radar systems have been recently developed with the progress in phased-array antennas and digital beam-forming technology [1]. However, the characteristics of multi-beam radar and its optimum design have not been sufficiently studied. In this thesis, a systematic design method for multi-beam search radar which clarifies the relation between radar parameters and theoretical performance is proposed. Beam-forming methods and their performance in new applications to which multi-beam radar technology is indispensable are also discussed.

The first half of this thesis describes a simple model which expresses the relation between radar parameters and search-radar performance for multi-beam radar and proposes an optimum design method to minimize equipment size using a nonlinear optimization technique to satisfy required performance.

Three specific merits of multi-beam radar compared with single-beam radar are described. First, it is theoretically clarified that improvement in Doppler resolution (that is, clutter suppression performance) is obtained without influencing other performances. Second, it becomes possible to apply a radar resource-management technique to control the number of beams and the beamwidths and to adapt to the radar environment. This technique improves in search data rate or clutter suppression. Third, detection performance is improved by using the correlation between signals received in the multiple beams. Here, new correlation methods for multi-beam radar -- Multiple thresholds detector and RMS detector -- are proposed for which the relation between beam spacing and required signal-to-noise ratio (SNR) is determined using numerical simulation.

The latter half of this thesis discusses beam-forming methods and search-radar performance for "bistatic radars" and "distributed-array radars" which is novel applications of multi-beam technology.

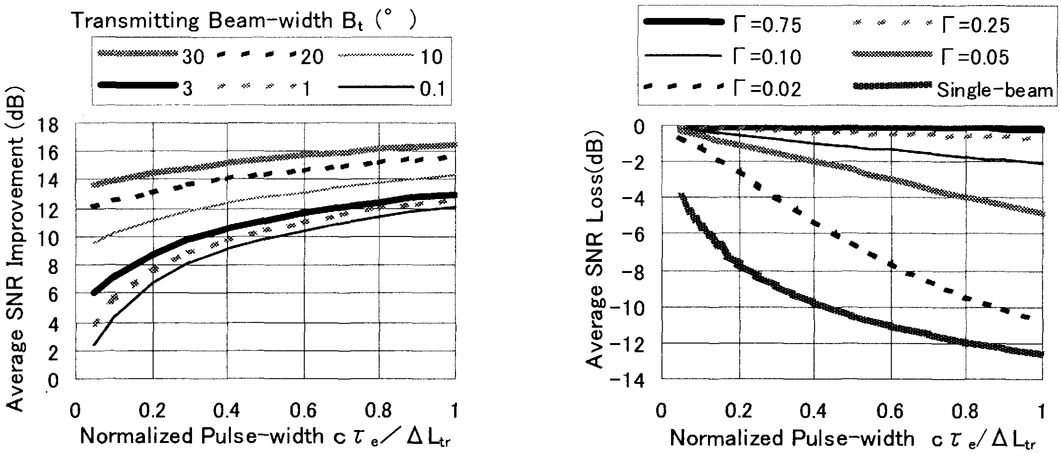
For bistatic radar the pulse-chasing technique using a single beam is a beam-forming method established for search-radar [2]. However, the required wider beamwidth and faster beamwidth control have been large obstructions to its utilization. Here the multi-beam pulse-chasing technique [3] using a receiving multi-beam stack is proposed as a means to avoid these problems, and the required number of beams and received SNR are discussed as a function of target position. The numerical examples show that the multi-beam pulse-chasing method achieves several decibels improvement of SNR compared with a single beam (Fig.1(a)). In addition, an improvement that reduces the number of beams (namely reduces necessary signal-processing) is proposed. This method treats a received signal for which a part of the pulse is lacking, as in the case of pulse-compression waveforms. The relation between the SNR loss and the ratio of upper limit and full number of beams is shown based on numerical calculations (Fig.1(b)).

Distributed-array radar [4] is an advanced and attractive concept in which a number of small sub-arrays are synthesized to provide high detection performance. However, the conventional data-independent beam-forming (NB) approach is unsuitable for such distributed sub-arrays because they produce many grating lobes. Therefore, for search-radar mode a novel blind multi-beam forming method that uses an eigenvector corresponding to the maximum eigenvalue of the sub-array-based input correlation matrix is proposed and its performance is investigated with numerical examples. This method provides both an increase in receiving-antenna gain in proportion to the number of sub-arrays and an expansion of the synthesized beamwidth relative to each sub-array's beamwidth, which can provide extreme improvement to search efficiency for distributed-array radars.

In addition, for the acquisition and tracking mode a norm-constrained diagonal-loading Capon beam-forming method (DL+NCCB) is proposed, which can provide a narrow beamwidth for higher spatial resolution. Moreover this approach prevents both the generation of grating lobes and excessive sharpening of the synthesized beam compared with the well-known standard Capon beamformer (SCB) [5], the fixed diagonal loading robust Capon beamformer (DLCB) [6], and the norm-constrained robust Capon beamformer (NCCB) [7] as shown in Fig.2. Then the influence of norm-constrained parameter (ε) and diagonal-loading parameter (ζ) on the grating lobes and beamwidth are investigated, and the relation between the optimum parameters and performance is shown based on numerical calculations.

It is expected that the technology of sensors including radars will evolve into network sensors that consist of distributed sensors and received data fusion based on multi-beam radar technology in order to satisfy various needs in an information society.

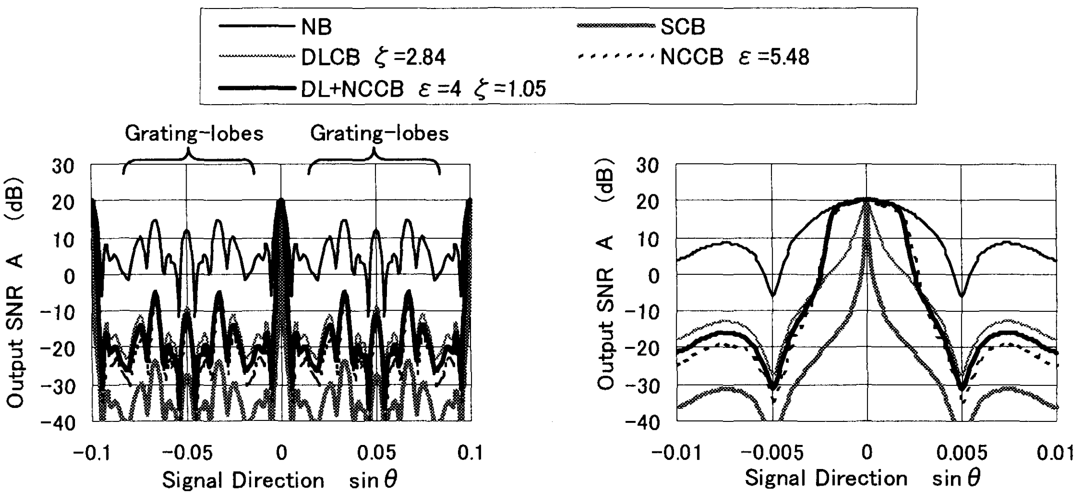
The basic performance and design method for multi-beam radar technology are clarified in this thesis, showing the direction of future radar research. Novel applications specific to multi-beam radar are discussed. Consequently, this study is expected to contribute to the development of research on future radars and related fields.



(a) Average SNR improvement of the multi-beam pulse-chasing compared with a single beam (Number of beams is not limitted)

(b) Average SNR loss via the ratio of upper limit and full number of beams Γ at multi-beam pulse-chasing (Transmitting beamwidth Bt=1°)

Fig.1. Received SNR performance of bistatic radar using multi-beam pulse chasing compared with single-beam.



(a) Output SNR

(b) Expansion of main-beam in (a)

Fig.2. Numerical examples of beamformer output of distributed array radar. (Number of subarrays=10 with 30λ and 40λ spacing, λ : wavelength)

REFERENCES

[1] Cheston, T. C. and Frank, J. (1990) Radar Handbook Second Edition, McGraw-Hill, New York Chap.7:7.1-7.82

[2] Hanle, E. (1986) IEE Proc, Pt.F, 133(7):587-595

[3] Matsuda, S., Hashiguchi, H. and Fukao, S. (2006) Electronics and Communications in Japan, Part 1, 89(1):11-21

[4] Heimiller, R. C., Belyea, J. E. and Tomlinsonr, P. G. (1983) IEEE Trans. Aerospace and Electronic Systems, 19(6):831-839

[5] Capon, J. (1969) Proc. IEEE, 57(8):1408-1419

[6] Cox, H., Zeskind, R. M. and Owen, M. M. (1987) IEEE Trans. Acoustics, Speech, and Signal Processing, 35(10):1365-1376

[7] Li, J., Stoica, P. and Wang, Z. (2003) IEEE Trans. Signal Processing, 51(7):1702-1715